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REVIEW

Ontologies for Liver Diseases Representation: A Systematic Literature Review

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Abstract
Ontology, as a useful knowledge engineering technique, has been widely used for reducing ambiguity and helping with information sharing. It is considered originally to be clear, comprehensive, and with well-defined format. It characterizes several domains purposes description through structured and formalized languages. In various areas of research, it has become a significant way to realize successful and powerful accomplishments. Actually, medical ontologies were turned into an efficient application in medical domains. They also become a relevant approach to process large medical data volumes. Consequently, they are behaving as a support decision system in some cases. Also, they ensure diagnosis process acceleration and assistance. Additionally, they have been integrated especially to represent human healthcare concepts. For that reason, plenty of research works applied ontologies to design and treat liver diseases. In this article, we present a general overview of medical ontologies to stand for this type of disease. We expose and discuss these works in details by a complete comparison. Also, we show their performance to arrange clinical data and extract results.

Keywords Ontologies · Liver diseases · Medical terminologies · Knowledge representation

Introduction

Liver cancer is one of the most deadliest and aggressive cancers in the world. According to the Global Cancer Observatory (GCO),[1] it is the sixth most common cancer in the world and the third most deadly. It mainly affects men over 40, most often with cirrhosis or hepatitis B or C. The US Center for Disease Control and Prevention (CDC)[2] mentions that each year in the USA, around 22,000 men and 8000 women get this disease, and around 16,000 men and 8000 women die from hepatic diseases. At early cases, it may not show any symptoms. In particular, hepatocellular carcinoma (HCC) and cholangiocarcinoma are considered the most critical and most frequent liver diseases that attack adults. Many factors can promote the development of these tumors (e.g., alcohol, obesity, diabetes, tobacco). The diagnosis of liver tumors is a complex and sensitive task. A possible long period of several months may be necessary to extract the hepatic nodule type.

[1] http://gco.iarc.fr/

[2] https://www.cdc.gov/

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Offering large databases of clinical information is an important but critical need for various medical applications. Medical terminologies offer a standard source of information that facilitates communication between radiologists, doctors, and the whole medical staff. Also, they allow dealing with domain knowledge reuse. Among these terminologies, we find (radiology lexicon) RadLex,[3] which is considered as a standard and a controlled terminology dedicated to radiology uses. It is a single, unified source of terms for radiological practice, education, and research. The purpose of RadLex is to provide a uniform structure for capturing, indexing, and retrieving a variety of radiology information sources, such as teaching files and research data. This may facilitate a first step toward structured reporting of radiology reports. This will also permit the mining of data for participation in research projects, registries, and quality assurance [1]. Also, Unified Medical Language System (UMLS[4]), which is developed by the United States (US) National Library of Medicine (NLM), allows the organization of clinical vocabularies [2]. In the same context, we can cite also the systematized nomenclature of medicine-clinical terms (SNOMED CT), Medical Subject Headings (MeSH[5]), transparent access to multiple bioinformatics information sources (TAMBIS[6]), foundational model of anatomy (FMA), the international classification of diseases (ICD[7]). In this article, we present a literature review that outlines the topic of using ontologies for liver diseases representation. This work addresses the problem of integrating knowledge engineering techniques to solve clinical problems.

The remainder of the article is organized as follows: Section 2 outlines the applied research methodology to synthesize studies. Section 3 exposes the reviewed works that deal with the topic of ontologies for liver diseases. Section 4 discusses the presented approaches, and finally, Section 5 summarizes the paper and gives an overview of future works.

Methodology

To restrict this article, we apply the systematic literature review (SLR) methodology [3]. The main goal of this methodology is to collect and analyze data extracted from studies selected in the article. It is based on three phases: (1) planning the review, (2) conducting the review, and (3) reporting the review. Each phase is explained in the next sections.

[3] http://www.radlex.org
[4] https://www.nlm.nih.gov/research/umls
[5] https://www.nlm.nih.gov/mesh/
[6] http://www.cs.man.ac.uk/~stevensr/tambis/details.html
[7] http://www.who.int/classifications/icd/en/

Planning the Review

This phase outlines the topic of the research by giving the research questions. It is dedicated also to develop the review protocol in order to guide the SLR. In this article, the research questions are:

RQ1: What are the sources used to carry out and collect medical data?
RQ2: Is there any reuse of a specific semantic vocabulary or framework?
RQ3: Did the proposed work expose a semantic representation of the ontological approach?
RQ4: Did the proposed solution generate any prototype accessible for download and reuse?
RQ5: Is there any description of the implementation strategy?
RQ6: Have the authors evaluated and validated their approaches by the use of real medical data?
RQ7: What are the tools and languages applied to develop the proposed model?

Two other questions related to the objective of each work and the applied methodology will be explained in the next section.

Search Strategy

To select adequate works, we focused on IEEE Xplore, Elsevier Scopus, Web of Science, Google Scholar, ScienceDirect databases. Specific terms were integrated to begin the search such as "medical ontologies", "liver cancer ontologies", "medical terminologies", "HCC ontologies", and "ontologies for medical imaging". We used also a combination of terms such as "ontologies for liver diseases" and "MRI imaging" to ensure adequate results.

Inclusion/Exclusion Criteria

The criteria are integrated to ensure that the studies focused on the boundaries of the research topic and its objectives. All articles were taken for their relevance to the domain of medical ontologies especially for liver diseases. Inclusion and exclusion criteria should response to research questions. They should be conducted to ensure that they can be clearly interpreted and that they classify studies correctly. In this article, the inclusion criteria are:

1) Studies published in the English language;
2) Studies published between the period of 2005–2019;
3) Studies within the domain of ontologies for liver diseases representation.

Table 1 Ontology for medical image interpretation using CT scans

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[4]	ImageCLEF 2014	ONLIRA, SVMs WNN	–	–	+	+	–
[5]	Medical images	FMA, ICD-10	+	MEDICO Ontology, RadSem	+	+	OWL, ImageJ
[6]	Radiological reports	VST, RadLex	–	–	+	+	Riesz wavelets, SVM
[7]	Medical domain experts	MEDICO-ontology, FMA RadLex	+	–	+	+	SPARQL OWL/RDF, Jena (TDB)

The exclusion criteria are:

1) Studies not published in English;
2) Studies outside the domain of liver cancer diseases and ontologies;
3) Duplicated works in electronic databases.

Conducting the Review

This phase is intended to identify the selected works strategy, select primary studies, and make a quality assessment, data extraction, and synthesis.

Search for studies

Our research was made on May 2019. We looked for studies that deal with the domain topic. We have selected 300 primary studies. These works expose medical solutions that validate the presence of ontologies as an effective solution to build or improve several computer-aided systems. We tried to study publications that have answered to the research questions.

Study Selection

To start the selection part, we eliminated redundant studies extracted from different databases. Therefore, we focused on the titles, abstracts, and keywords of each study to select the most adequate publications. Then, we started our study with a total of 39 works. These works presented semantic representation samples that deal with liver disease, especially with HCC. The numerous terminologies related to liver cancer have been represented by different ontological approaches enabled for clinical purposes. The next section is dedicated to present an overview about these approaches related to liver disease models.

Reporting the Review

We present in this section three categories of research areas that deal with improving knowledge engineering achievements in medical purposes, ontologies for medical image interpretation, ontologies for medical data representation, and ontologies for radiological report examination. More details about these categories are mentioned in the next subsections.

Ontology for Medical Image Interpretation

This category of works extract in medical images features and clinical characteristics. Hereafter, they use these data to realize an ontological model addressed to medical issues. We devise this category into three groups according to the medical image type; computed tomography (CT) scans, magnetic resonance imaging (MRI), and other types.

CT Scans Interpretation

In the field of medical images annotation, [4–6] presented semantic tools to detect liver lesions. Beginning with [4], it improved content-based image retrieval (CBIR) methods to allow automatic liver CT scans annotation. The proposed method interprets semantically these images. Consequently, it describes image characteristics such as 3D objects, liver specificities (i.e., intensity and size), tumor information (i.e., intensity, shape, density, location, and size), and vessel information (i.e., size). This work proposed a weighted nearest neighbors (WNN) based method as a data recovery strategy

Table 2 Ontology for medical image interpretation using MRI images

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[8]	Medical images	FMA	+	–	+	+	OWL-DL
[9]	Medical images, radiological reports	–	+	OntHCC	+	+	Protégé, SWRL, SPARQL, OWL
[10]	Radiological reports	FMA,PATO, MPATH, RadLex, ChEBI, DOLCE,RDF	+	OntoVIP	+	+	OWL-DL

Table 3 Ontology for medical image interpretation using other images' types

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[11]	NCI's Early Detection Research Network (EDRN)	GO, OBO	+	QHIO	+	+	Protégé, OWL
[12]	_	RDF, JDOM	−	BCO	+	+	Protégé, OWL-DL, SWRL, SPARQL, WFML, RuleML, Java
[13]	PET-CT imaging studies	AIM annotations	+	−	+	+	Protégé, RDF/OWL, ePad, SPARQL
[14]	NCI, caBIG	AIM, RadLex, MIAME project	+	−	+	+	Protégé, DICOM, HL7 CDA (XML), OWL

following search queries. The contribution part integrated 3D volumetric images extracted from ImageCLEF 2014 Liver CT annotation challenge, these data are 73 annotations processed via ONLIRA ontology. [5] proposed the MEDICO ontology, it gathers clinical information extracted from other ontologies (i.e., FMA) together with medical terminologies (i.e., ICD-10 and RadLex). To ensure this model, several steps were followed: (1) developing an ontology-driven metadata extractor for the DICOM format. (2) Using the output to simplify manual annotation, (3) associating the extracted metadata with anatomical annotations and clinical results (4) performing query extensions, and (5) combining patients, medical images, and annotations in a complete list of results. [6] proposed a framework for modeling liver lesions using CT scans. It is used to predict radiologists' interpretations. The applied methodology starts by extracting terms referring to hepatic lesions. The next step consists in calculating the distance between all the generated visual semantic terms (VST) models. The goal is building an ontology that collects all terms and synonyms. To evaluate this approach, 74 cases of annotated liver injury with 18 VST models were taken from the RadLex ontology. Additionally, [7] proposed semantic method that enables physicians the intelligent search on medical databases. Table 1 shows a summary of the studied works.

MRI Interpretation

MRI interpretation is mentioned in [8], this approach offered an ontology that guides image interpretation and allows its biomedical structures recognition. This model was enriched by fuzzy conceptual representations. Also, it established links between these concepts. It offered a framework for knowledge domain representation and reasoning. Moreover, it reduced semantic gaps between the digital information and its conceptual level. For cerebral anatomical concepts representation, this work uses FMA ontologies. The assessment has been conducted with 3D brain MRI images. Furthermore, [9] proposed an ontological model OntHCC for liver cancer representation. This model focuses especially on HCC detection from the medical image, HCC classification through a staging system, and HCC treatment. It developed a Java software that enables communication between users and machine via graphical demonstrators. This work has included SWRL rules to achieve the reasoning process. The developed ontology is populated with clinical data extracted from real medical reports and related to HCC patients. In [10], the goal is to annotate medical images information by semantic methods. The developed prototype (OntoVIP) enabled the reuse of these information in several clinical applications. Also, it allowed medical image simulation. Table 2 exposes these works.

Other Medical Images Interpretation

Using ontologies for medical features extraction is mentioned in [11–13]. [11] proposed a model medical image data representation. It looked for merging regularly the pathological quantitative image information with its associated clinical data. A prototype named Quantitative Histopathology Image Ontology (QHIO) was developed. It contains various pathological images and computational algorithms. It is dedicated to refine the previous developed approaches by trying to improve the annotation tools. This methodology is composed of four essential parts: an input (e.g., image), parameters (e.g., size of the filter window sizes, number of iterations), an output (e.g., image, measurement), and the execution step. For [12], it used semantic reasoning techniques to analyze whole-slide images (WSI). This work generated a system for biological objects recognition and extraction. In addition, it is used to apply an image analysis engine to release the visual medical information. The applied methodology allowed its integration into various pathological domains platforms and increased the sensitivity of low-level medical image analysis algorithms. In [13], the goal is extracting information from the medical image. This work focused on building a structured database of nuclear medical images using the Annotation and Image Markup (AIM[8]) annotation. This approach developed a template for the nuclear medical field applied to annotate 100 positron emission tomography-computed tomography (PET-CT) images. This annotation is made using the vocabularies RadLex, FMA, and SNOMED CT. Query language for RDF

[8] https://wiki.nci.nih.gov/display/AIM/Annotation+and+Image+Markup+-+AIM

Table 4 Ontology for liver cancer staging

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[15]	Medecine.net Cancer.org Indiahospitaltour.com Healthline.com	–	+	–	+	+	SPARQL, OWL, Protégé
[19]	Cancer.Net, MedicineNet, NCI	–	+	–	+	+	Protégé-OWL
[16]	MedicineNet CancerNet, NCI	–	+	–	+	+	Protégé-OWL, OWL-DL
[20]	Domain experts and medical books	OBR	+	–	+	+	Protégé, OWL
[21]	N/A	–	+	–	+	+	Protégé, XML, RDF(S), DAML+ OIL OWL
[22]	Web	–	+	VHOSWS	+	+	OWL, C#, ASP.NET
[23]	Medical databases	–	+	–	_	+	Protégé, OWL API, IDE, Fact++, OWL-DL
[24]	NCBO	OBO, FMA, CO, PRO, CO, CC, GO, BP	+	LIO	+	+	Protégé
[17]	Hospitals	FMA, BioTopLite2	+	TNM-O	+	+	OWL-API, Java, Hermit reasoned
[25]	Medical databases	Chinese library classification (CLC) MeSH	+	Hepatitis ontology	+	+	OWL, Protégé,
[18]	Stanford University	ePAD, AIM	–	–	+	+	OWL, SPARQL, SWRL
[26]	ASAS	–	+	–	+	+	OWL 2.0, Protégé 4.1, OWL-DL 2.0, Hermit 1.2.2 reasoner

(SPARQL) queries were integrated to test the effectiveness of the proposed system. Rubin et al. [14] proposed a tool enabling the semantic annotation of medical images in digital imaging and communications in medicine (DICOM) format. The proposed method used medical images contents to create a communication tool. This box makes the collection of image interpretations and observations easier. The proposed approach is composed of three phases: (a) creating ontology that provides a standard model of semantic annotations, (b) developing an image annotation tool that collects these annotations, and (c) serializing medical data by the use of HL7, CDA XML, and OWL as languages to allow data access on the Web. These works are presented in Table 3.

Ontology for Medical Data Representation

Various research works deal with the problem of modeling liver cancer diseases by the use of semantic representation. They take into account the importance of knowledge engineering in supporting clinical decision.

Ontology for Liver Cancer Staging

To classify liver cancer, [15–18] used the (tumor, node, metastasis) TNM system. [15] presented an ontology-based approach dedicated to liver cancer diagnosis. The basic concepts included here are symptoms, risk factors, diagnosis via clinical tests and medical imaging, predicting the existence of the liver cancer, and extracting its stage (e.g., localized, regional, or distant). Liver diagnosis is presented by including the classes: risk factor, symptoms, diagnosis, treatment, investigation, and prognosis of liver cancer. To manipulate and acquire data inside the ontology, SPARQL[9] is applied. [16] created a web application designed to enable easily the extraction of liver-related information. It ensured a valid source of information. It can be visited by users and researchers supporting medical fields. [17] proposed an application dedicated to cancerous tumors classification. A TNM ontology (TNM-O) has been developed. The data must be included through graphical demonstrators or tables of information. Classification part begins by creating a RDF file that contains all individuals of the ontology. [18] is also applied to extract malignant tumors stages. AbdelBadih et al. [19] summarized works done by the same authors in the field of integrated knowledge engineering for liver cancer diagnosis. The general idea is to improve ontological engineering efficiency to solve medical informatics issues. Among these works, [20–23].

In [20], the main idea is to present viral hepatitis through an OBR (ontology of biomedical reality)-based ontology for viral hepatitis. Three main aspects were followed in this approach: (i) medical terms extraction; (ii) liver diseases classification; (iii) a validation phase. Additionally, [22] offered a service that details liver diseases, diagnosis process, and suitable treatment. Viral hepatitis ontology sharing and diagnosis (VHOSWS) implementation goes through two necessary components; (1) developing an ontology-based web service (2) offering a shareable application between physicists, doctors, and students. Results were returned in OWL files that contain full description for viral hepatitis, symptoms, signs, and clinical findings. [23] gave an overview about medical

[9] http://www.w3.org/TR/rdf-sparql-query

Table 5 Ontology for other medical issues

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[27]	DICOM data	Dcm4che	−	−	+	+	RDF, SPARQL, Java
[28]	Case-based reasoning (CBR) database	LOINC, SNOMED	+	−	+	+	RDF
[29]	Medical images (CT)	ONLIRA	+	−	+	+	−
[30]	Medical imaging, radiological reports	SNOMED-CT, LOING, ICD-10-M, ONLIRA, RadLex	+	LiCO	+	+	Protégé, SWRL SPARQL, OWL
[31]	Medical terminologies	DO, MeSH, UMLS, SNOMED-CT, ICD-10	−	LiverAtlas, HuIDO, (Human Liver Disease Ontology)	+	+	−
[32]	US Food and Drug Administration (FDA) histopathological reports	UMLS, SNOMED	+	DILIO	+	+	Protégé, OWL
[33]	−	CLC (Chinese library classification) MeSH	+	+	+	+	Protégé 3.4.1, OWL, Jena environment

ontologies focusing generally on cancerous diseases. This work is based on classification systems that extract patient related tumor type, the stage and the adequate treatment that can be applied after. Three essential modules were followed: (1) diagnostic module; (2) staging module; and (3) processing module. In [24], there is a presentation of Liver Immunology Ontology (LIO). It provided information describing immunological reactions in the context of liver cancer. The development of LIO starts by (i) extracting ontological terms from related works dealing with the same problem gender, (ii) giving more expressiveness to the extracted words, and (iii) combining the selected terms with extracted terms to form detailed descriptions. Additionally, [21] presented a classification system for liver diseases based on the previous developed ontologies like VHOSWS [22] and LIO [24]. This work described a global view of the hepatobiliary system including liver organ. It exposed also studies allowing liver disease classification. Several authors have attempted to apply ontologies to classify patients [18, 25, 26]. These approaches are intended to automatically classify real patient cases. To this end, they used diagnosis criteria to successfully classify diseases. Table 4 exposes these approaches.

Ontology for Other Medical Issues

In this category, we present works that have integrated ontologies for various clinical issues. [27] proposed a method allowing the semantic representation of medical data. This work has two main objectives: (1) saving the common data extracted from a DICOM file as an RDF file, (2) calculating medical images biomarkers and saving them as a RDF file. [28] presented a treatment approach based on holistic information processing in order to get a surgical decision support. This work presented a formalized patient model to achieve a solid treatment process. [29] used case retrieval in radiology (CaReRa) project, which includes Clinical experience sharing (CES) concepts, to treat liver cancer. Among the accomplishments of this project was the generation of the ontology ONLIRA. This work is based on real cases of patients and it is intended to test semantic annotation level of medical observations. The test is performed on portions of liver CT images based on the computer generated (CoG) features. [30] proposed liver case ontology (LICO) to model real cases of patients infected by liver diseases. This approach reused medical terminologies and vocabularies (e.g., ICID-10-CM, SNOMED-CT, ONLIRA, RadLex, and the logical observation identifier names and codes (LOING)[10]). To achieve this approach, these steps were followed: (i) modeling the ontology, (ii) validation of LiCO, and (iii) testing with reasoning queries. For each studied patient case, authors have collected large quantity of information that mainly concern the medical history (e.g., previous surgeries), blood tests results, radiological observations, liver, and lesion. [31, 32] provided respectively large databases of clinical data through LiverAtlas and drug-induced liver injury (DILIO) ontologies. They are dedicated to cover liver diseases data, identifying hepatic lesions markers [31], and describing liver injuries [32]. [33] outlined the important role of knowledge engineering representation on clinical research. Table 5 gives a summary of these works.

Ontology for Radiological Report Examination

This category outlines approaches that have integrated ontological models to analyze and organize medical reports. The goal is offering large databases of clinical information and tool. Two parts in this category: (1) modeling HCC reports and (2) modeling other liver diseases' reports.

[10] https://loinc.org/

Table 6 Ontology for radiological report examination

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[34]	Radiology reports	SNOMED, EHR, PubMed	–	_	+	+	UMLS, BRAT software
[35]	Radiology reports	–	+	MROnt	+	+	Protégé, SWRL, OWL
[36]	Abdominal radiology reports	MetaMap WordNet	–	–	+	+	UMLS

Modeling HCC Reports

Modeling HCC reports via semantic representation is the objective of this section. In this context, [34–36] presented ontological approaches to analyze medical reports. For [34], it proposed an electronic health record (EHR) based system dedicated to deal with medical data. Three phases in this approach, (1) collecting real radiological reports tacked randomly, (2) extracting information from the treated cases, and (3) clinical terms, were extracted according to SNOMED CT vocabulary. In this work, authors used 112 abdominal CT images; 59 images referring to HCC metastases and 53 classified as no abnormality detected (NAD) group. The proposed system has generated 30 concepts. Among these concepts are abdominal organ finding, blood vessel finding, disorder of digestive system, disruption of body system. The comparison step generated two groups of terms respectively connected to the HCC and NAD groups. In the case of HCC, the system offered clinical guides to add decision support tools including the treatment to be applied. The accuracy and the sensitivity reached 88.4 and 84.7%, respectively. [35] also developed the medical reports ontology (MROnt) to analyze medical reports. It used semantic meaning of reports to analyze medical reports for MRI patient exams. The proposed approach is composed of two major steps: (1) the reports modeling step includes the ontological model MROnt, (2) the report analyzing step. In [36], the applied technique consists in identifying textual expressions describing real entities. This work proposes an algorithm that takes a tumor as an input and carries out features (e.g., size and stage). Other informations were indented to be extracted like the largest malignant tumor, nodule number and if 50% of the liver was damaged or not. This approach used American Joint Committee on Cancer (AJCC), Barcelona Cancer of the Liver Clinic (BCLC), and Cancer of the Liver Italian Program (CLIP) as classification systems. A database containing 101 abdominal radiology reports was prepared for 160 patients suffering from HCC. This database contains globally 3211 entities, 2283 relationships, and 1006 tumor models. These reports are annotated using 7 entities (e.g., anatomy, measurement, tumor reference). Relationships were applied to link these entities. To annotate radiological reports, two types of semantic expressions were included, they are coreference and particularization. To annotate the reference resolution, the approach uses the following annotators MUC, B-cubed, and CEAF. Table 6 illustrates this category of works.

Modeling Other Liver Diseases' Reports

This category is dedicated to present works that have focused on ontologies for radiological reports examination. [37, 38] presented both ontological prototypes for modeling liver reports. [38] developed an ontology-based application named

Table 7 Ontology for radiological report examination

Approach	RQ1	RQ2	RQ3	RQ4	RQ5	RQ6	RQ7
[38]	Radiology reports	RadLex, FMA	+	RadiO	+	+	Protégé
[39]	Radiology reports	SNOMED-CT	–	–	+	+	CLEF, myGrid
[40]	Radiology reports	UMLS, HUGO Gene Nomenclature database	–	AMBIT	+	+	–
[41]	Radiology reports	OBO, RO, OGMS, IAO, OBI, PATO,UO FMA	+	MCI ReportViewer	+	+	SPARQL, RECIST
[42]	Radiology reports	RGO,HPO, DO,	+	–	+	+	NCBO Annotator
[37]	Radiological reports	RadLex	+	ONLIRA	+	+	OWL

Table 8 Concepts of used ontologies

Ontology	Hepatitis ontology	ONLIRA	LiCO	LIO	Web-based liver cancer	OBR viral hepatitis	DILIO	Liver cancer ontology [16]	OntHCC [9]	MROnt [35]
Number of Concepts	44	56	93	49	25	15	200	42	49	22

the radio ontology (RadiO) to examine radiological reports. The first step is collecting radiological observations noted by radiologists while diagnosing patients. The second step representing knowledge about medical images entities and their characteristics. Finally, an FMA-based ontology was created in order to provide a structured knowledge base of medical imaging. In [37], the goal is modeling medical CT reports. This approach realized standard vocabularies of the clinical terms. It extracted medical terminologies from RadLex vocabulary [1]. The method is based on three main steps: (i) radiological representation of concepts, (ii) individual properties extraction (e.g., liver size and density), and (iii) relationships construction. Among the used concepts, we find "Liver", "Lesion", and "HepaticVascularity". To evaluate this approach, 30 radiological reports related to different patients were transformed as instances of the ontology. A list of queries was prepared to manipulate the data applying natural language processing (NLP) techniques. This ontology is named ontology of liver for radiology (ONLIRA)[11] and it has been validated by experts.

Other works such as [39] [40–42] have focused on offering a standard vocabularies for clinical reports. [39] used NLP techniques to solve research problems in clinical routines. To achieve this goal, ontology has been integrated to realize clinical terminologies recognition and standardization. In the same context, [40] proposed a processing framework for aquiring medical and biological information from text (AMBIT) system. It is a text analysis system, dedicated to extract clinical information from medical and biomedical documents. Also, it integrated information technology (IT) aspects. Subsequently, these insertions will be saved in a well-structured format for clinical purposes. It is based on two aspects: a terminology engine named Termino and a query engine that allows users access to the saved information. AMBIT includes 160,000 terms imported from UMLS. Eighty-three examples of radiology reports describing lung cancer are applied to test the effectiveness of this system. [41] proposed the Model for Clinical Information (MCI) system. The objective is offering a structural representation for radiologist's notes. It reused various ontologies (e.g., Relations Ontology (RO), Ontology for General Medical Science (OGMS), Information Artifact Ontology (IAO), the Ontology for Biomedical Investigations (OBI), FMA). This system contains 551 classes, 107 object properties, and 33 datatype properties. [42] used biomedical ontologies to diagnoses several human diseases. This approach mapped the Radiology Gamuts Ontology (RGO) concepts to other ontologies (e.g., Disease Ontology (DO) and the Human Phenotype Ontology (HPO)) in order to characterize human diseases. Table 7 summarizes these works.

Discussion

All the studied works deal with the topic of applying knowledge representation to medical issues especially for liver diseases representation. In fact, many current research works have generated prototypes such as ONLIRA [37], LiCO [30], VHOSWS [22], HulDO [31], and LIO [24]. To validate these approaches, there exist several followed techniques to improve the proposed work efficiency. Some works try to use standard measurements such as recall and accuracy percentages, techniques used by [13, 34]. Other works test their approaches with real data extracted mainly from clinical and medical sources. Furthermore, querying and manipulating the ontology by integrating semantic search queries (e.g., SPARQL rules) are also applied in [15, 36, 37].

In the context of liver diseases modeling, some research works have presented a comparison of medical ontologies. Among these works, we find [43]. It takes into account different medical care ontologies and classifies them depending on the topic usage percentage (i.e., diseases, cancer). Then, we choose nine accessible ontologies that deal with liver cancer representation. These ontologies are hepatitis ontology [25], LiCO [30], ONLIRA [37], LIO [24], web-based liver cancer ontology [16], OBR viral hepatitis [20], DILIO [32], liver cancer ontology [16], HuLDO [31], OntHCC [9], and MROnt [35]. After that, we eliminate HuLDO [31] ontology from the comparative study because we did not find a clear representation of its conceptual architecture. Also, for LIO [24] ontology, we used just its accessible concepts. Table 8 presents the applied ontologies.

To compare these ontologies, we focus on common concepts in order to visualize their similar aspects. Figure 1 exposes our comparing study. Among common concepts shared between ontologies, we find "Acute Hepatitis", "Chronic Hepatitis", and "Viral Hepatitis" which are used respectively by hepatitis ontology and DILIO. Furthermore, "Treatment", "RiskFactors", "Diagnosis", "Symptoms", and "LiverCancer" concepts are used

[11] https://bioportal.bioontology.org/ontologies/ONLIRACaReRa-WEB

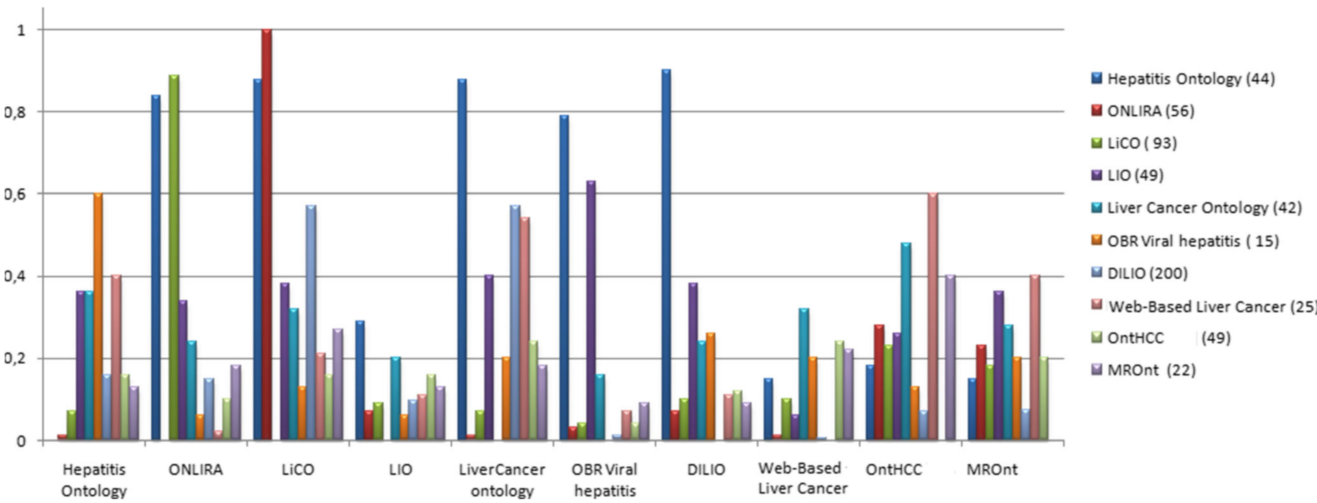

Fig. 1 Assessment of liver diseases' ontologies

commonly by web-based liver cancer and liver cancer ontologies. There exist different concepts which are written in different ways but they refer to the same context such as "LabResults" and "Laboratoryresults" related to LiCO and OBR viral hepatitis ontologies. Moreover, we find that all ONLIRA concepts are included in LiCO ontology. To focus on the most applied concepts between all ontologies, we propose another comparative study that outlines these concepts. Figure 2 presents the common concepts applied in different ontologies. According to our study, we conclude that the most useful concepts are "TypesLiverDisease", "RiskFactors", and "Symptoms" because they have the highest frequency rate. Moreover, to enrich our comparative study, we calculated for each used ontology the percentage of its correspondence with the rest of ontologies. The findings are shown in Fig. 3.

Conclusion

This paper is dedicated to making an overview of liver disease representation by means of medical ontologies. This type of cancer is considered among the most deadly diseases in the world. Its importance and impact make this tumor an interesting subject for plenty of works. All the studied works improve the importance of semantic knowledge to treat medical areas and realize clinical accomplishments.

Our goal was looking for these works and comparing the different proposed issues by using some comparative criteria (e.g., tools, languages, prototypes). Also, this paper discusses how ontologies can facilitate communication between the whole medical staff. Ontologies were introduced in the most parts of the disease diagnosis such as the therapy process and behave additionally as a decision support system. In this

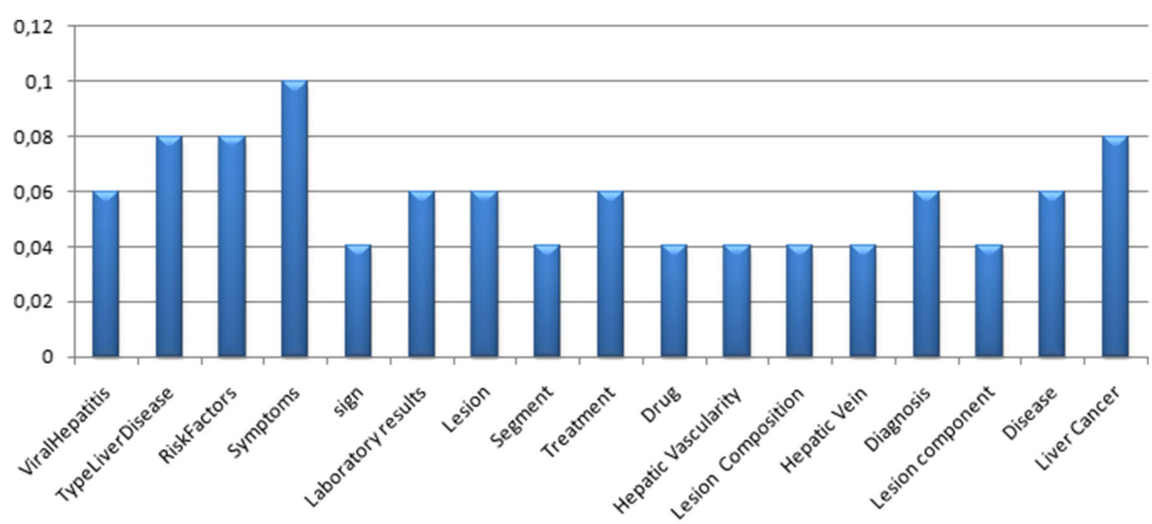

Fig. 2 Concepts usage frequency

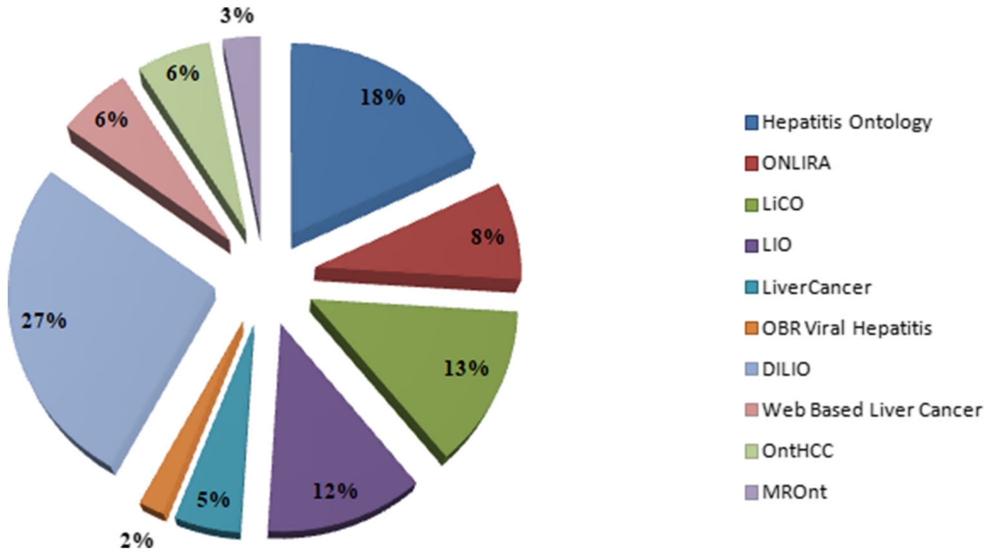

Fig. 3 Ontology correspondence percentages

article, we choose recent ontologies that deal with the topic of liver diseases representation via semantic models. We presented a conceptual comparison in order to provide the most relevant ontology as show in the obtained findings.

As future works, we aim to stand up our approach and overpass the gaps of currents works. We will concentrate on the topic of applying semantic models for liver cancer extraction from medical imaging (e.g., MRI and CT). The goal is to develop a tool that can be used by radiologists and doctors to assist on liver diseases detection.

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